3-D Magnetic Measurement of Neuromagnetic Response of Somatosensory Area to Different Repetition Frequencies

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ABSTRACT

A 3-D magnetic measurement of the bilateral somatosensory evoked fields (SEFs) by electric stimulus to the right thumb for four normal subjects were carried out, using a three-dimensional (3-D) second-order gradiometer connected to 39-channel SQUIDs, which can detect magnetic field components perpendicular to the scalp (Br) and tangential to the scalp ($B\theta$, $B\phi$) simultaneously. To discuss the relationship between the phase lag and stimulus repetition frequency (SRF), the delay time of a component synchronous with the SRFs (1.99 to 27.02 Hz) were calculated by the convolution of the reference signal and the SEF wave (BPF: 15-40Hz). The phase lag characteristic to the SRF in the contralateral hemisphere to the stimulus was linear in the ranges below 8 Hz and above 8 Hz in all magnetic components. The phase lag characteristic of the ipsilateral hemisphere to the stimulus was linear in only below 8 Hz in all components. It was tested for significance of the linear regression slope ($\beta \neq 0$, $P<0.05$).

KEY WORDS

Contralateral hemisphere, Inter-stimulus interval (ISI), Ipsilateral hemisphere, Somatosensory evoked field (SEF), Stimulus repetition frequency (SRF), SI activity, SII activity, Three-dimensional (3-D) magnetic encephalogram (MEG).

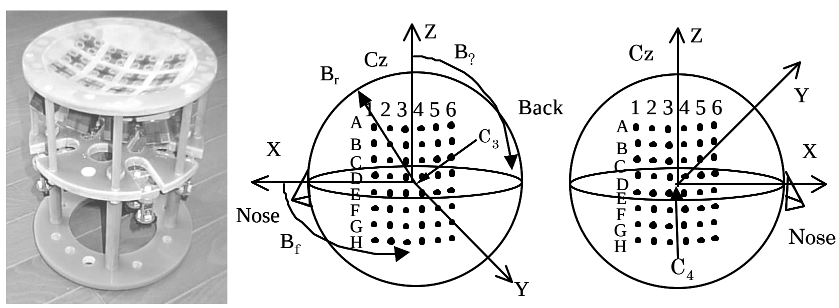
INTRODUCTION

Magnetoencephalogram (MEG) measurement of the magnetic field perpendicular to the scalp is widely used for research on brain function. We have developed a three-dimensional (3-D) second-order gradiometer connected to 39-channel SQUIDs for vector measurement of the MEG that can detect magnetic field components perpendicular (Br) and tangential ($B\theta$, $B\phi$) to the scalp simultaneously [Kobayashi K., 1999].

There are a few reports about the phase lag characteristic of the SEF with a variation of the SRF which was defined as a reciprocal of inter-stimulus interval [Brenner D., 1978], [Kuriki S. 1987]. They showed the phase lag characteristic of the contralateral neuromagnetic responses to the SRFs in somatosensory area. An aim of this study is to discuss the phase lag characteristic of the neuromagnetic responses with the SRFs obtained from both ipsilateral and contralateral somatosensory area using a 3-D MEG measurement.

METHODS

Four normal subjects participated in a 3-D MEG measurement. The 3-D MEG measurement of bilateral SEF with an electric stimulus to the right thumb was carried out, using 3-D second-order gradiometers connected to 39-channel SQUIDs, Fig.1 shows arrangement of pick up coil for MEG (fig.1 (a)) and measurement points on a subject's head (fig.1 (b)). The 3-D second-order gradiometer is wound with Nb-Ti wire on a rectangular solid of $3\times3\times6$cm.The 3-D MEG measurement of SEF was done in a magnetically shielded room. Black circles in fig.1 (b) show the measurement points and C_3 and C_4 are corresponded to ten-twenty electrode system. The SEF was elicited by electric pulses of 0.2 ms duration with 3.0 to 6.5 mA to the right thumb. The SRF was varied from 1.99 to 27.02 Hz. The sampling frequency was 1 kHz. And analog filter was used in the range from 0.5 to 300 Hz. All magnetic data were averaged for 400 measurements at each position. Digital filter was used in the range of 15 to 40 Hz [Kim BS., 2003].



(a) (b)

Fig.1 Arrangement of pick-up coil for MEG (a), and measurement points for bilateral SEF measurements (b).

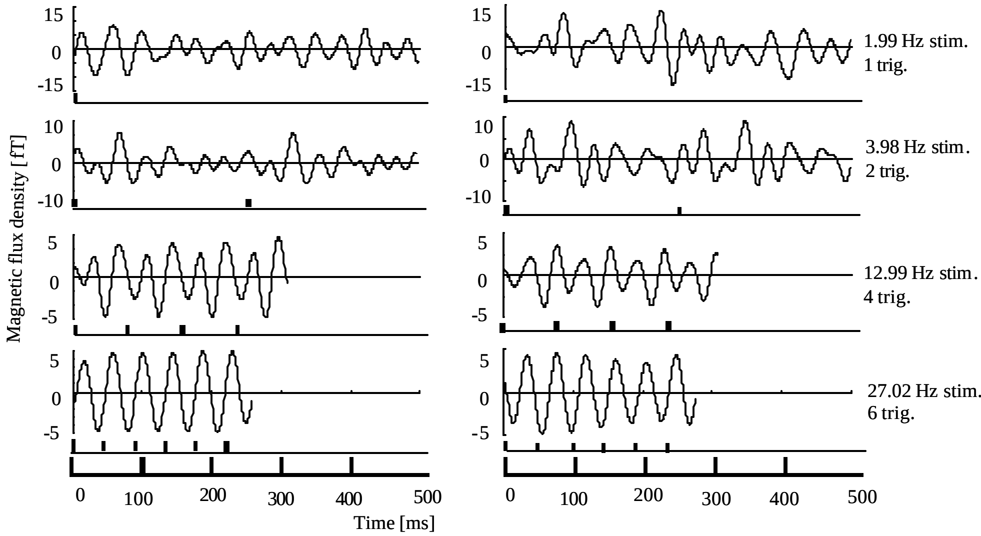
RESULTS

Fig.2 shows typical waveforms of the SEFs of Br component measured at both hemispheres (contralateral: F4, ipsilateral: F3 in Fig.1 (b)). The timing of current pulse delivered to the right thumb is indicated by black bars below each waveform. The waveform of 1.99Hz of the contralateral in fig.2 shows transient waveform having dominant peaks in some latencies. When the SRF was increased, amplitude of the SEFs was decreased and the neuromagnetic response became continuous waveform. Continuous waveforms were observed in the SRF of 27.02Hz. Transient waveform of the ipsilateral hemisphere shorter than about 80 ms latency did not appear significant peak comparing with the contralateral hemisphere. When the SRF was increased, the waveforms of the ipsilateral SEFs became a continuous as contralateral hemisphere.

DISCUSSION

In order to obtain the phase lag characteristic to the SRF, the delay time of a component synchronous with the SRFs (1.99 to 27.02 Hz) were calculated by the convolution of the reference signal and the SEFs. Fig.3 shows the relationship between the calculated phase lag and the SRFs,

which were averaged in four subjects. In this calculation the SEF waveforms were chosen at the point of F4 (contralateral) and F3 (ipsilateral) in Fig.1 (b). The phase lag characteristic to the SRF in the contralateral hemisphere was linear in the ranges below 8 Hz (Br: t1=157.2 ±33.0ms, Bθ: t1=177.2±6.8ms, Bϕ: t1=188.1±5.2ms) and above 8 Hz (Br: t2=36.5±12.4ms, Bθ: t2= 42.4±14.5ms, Bϕ: t2=47.2±30.9 ms) in all magnetic components. The phase lag characteristic of the ipsilateral hemisphere was linear in only below 8 Hz (Br: t1=141.1±9.0ms, Bθ: t1=132.1±30.7ms, Bϕ: t1=154.1 ±18.4ms) in all components. These were tested for significance of the linear regression slope ($\beta \neq 0$, $P<0.05$). In above the SRFs of 8 Hz (Br: t2=8.5±11.0ms, Bθ: t2=5±5.3ms, Bϕ: t2=4.5 ±6.5ms) in ipsilateral hemisphere, however, it was no significance of the linear regression slope. It was found that the result of ipsilateral hemisphere was caused by SII activity [Lueders H., 1983]. And it was also found that the result of contralateral hemisphere was caused by the activation of somatosensory area including both the SI activity and the SII activity. Further study is necessary to design and make modeling of neuromagnetic network to the somatosensory area by using a 3-D MEG measurement.



(a) contralateral (b) ipsilateral

Fig.2 Examples of SEF waveforms with the various SRFs (Br component, left panel is contralateral hemisphere and right panel is the ipsilateral)

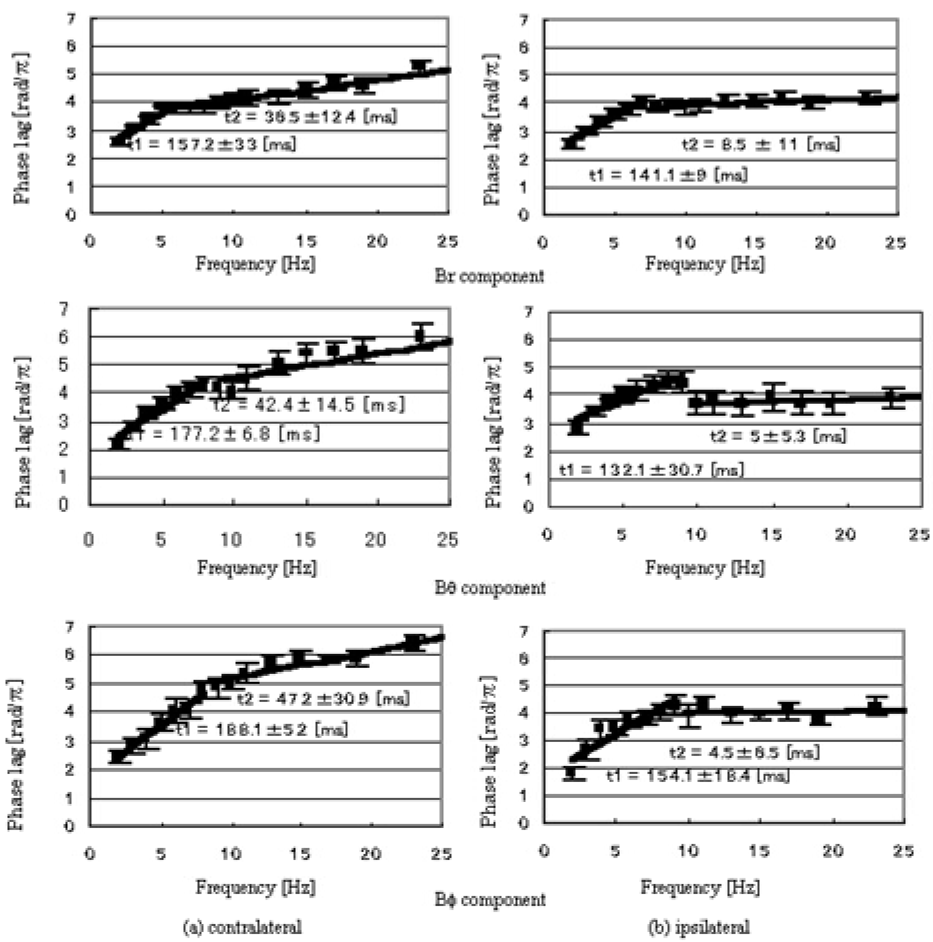


Fig.3 Averaged phase lag characteristic of each magnetic component for four subjects (left panel (a) is contralateral hemisphere, and right panel (b) is the ipsilateral to the stimulus.

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REFERENCES

Brenner D, Lipton J, Kaufman L, and Williamson SJ, somatically evoked magnetic fields of the human brain, Science, 1978; 199: 81-83.

Kim BS, Uchikawa Y, Separation of overlapping activity in first and second somatosensory evoked fields with 3D MEG measurement, IEEE Trans. Magn., 2003; Vol.39, No.5: 3387-3389.

Kobayashi K., Uchikawa Y., Development of a three-dimensional biomagnetic system with 39-channel SQUIDs. in Recent advances in biomagnetism. T yoshimoto et al., Eds. Sendai. Tohoku University Press. 1999, 35-38.

Kuriki S., Mizutani Y., and Isobe Y., transient and continuous response of neuromagnetic field evoked by peripheral verve stimulus, IEEE Trans. Magn., 1987; MAG-23: 1068- 1072.

Lueders H., Lesser RP., Hahn J. et al., Cortical somatosensory evoked potentials in response to hand stimulation, J. Neurosurg., 1983; 58: 885-894.